

50X1-HUM

(IMPACT STRENGTH)
~~THE MECHANICAL PROPERTIES OF METALS AT -253°C~~

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Abstract

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The authors worked out a procedure for the rapid measurement of the ~~toughness~~ ^{impact strength} of specimens at temperatures of liquid nitrogen and liquid air (-196 and -253°C). They give the results of ^{these} ~~measurements of toughness~~ conducted at -196 and -253°C upon three types of metals: Copper M-3, brass LS-62 and 59.

Introduction

Some of our previously published works cited the results of investigations into the mechanical properties of metals and a number of alloys at low temperatures (vide Kostenets, pp 515, 527, 539, 551 in ZHIF Vol XVI, 1946). They showed that all metals and alloys that possess the lattice of a face-centered cube, such as pure metals, austenite steels, nonferrous alloys, maintain their strength for decreasing temperatures down to -253°C, with some metals even increasing their strength. These results permitted scientists to make a more expedient selection of materials for low-temperature apparatus construction and machine studies. ~~[Note: The Russian word literally translated "impact strength" is called in English either "toughness" or "resilience".]~~

It is essential that we widen these researches to include experimental tests involving impact loads.

Similar tests were conducted in 1939 by Pomp, Krisch, Haupt (vide Mitt. Inst. für Eisenf. XXI, 219 and 281), who were the first to measure

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~~the toughness~~ ^{impact strength} at -253°C , of 28 types of various steels and also of nickel, copper, and lead.

Their method, however, suffered great losses in liquid hydrogen for maintaining the constancy of the specimen's temperature at the moment of impact and did not allow the rapid measurement of ~~toughness~~ ^{impact strength} at -253°C for a large number of specimens.

According to their method, each specimen is placed in the clamps of a ram impact machine in a closed two-ply paper box with woody padding, in which liquid hydrogen is poured. After this, the Dewar flasks with liquid hydrogen are removed and the impact test is conducted about 10 seconds after the conclusion of pouring.

The complexity of this procedure resulted in the fact that, apart from this one work, no other report on impact tests at hydrogen temperatures have appeared in print since.

Our report describes a method that permits one to conduct, with small loss of liquid hydrogen, such tests on an ordinary pendulum ram impact instrument, with standard specimens. The procedure is convenient for tests also at very high temperatures.

According to our method, each specimen is preliminarily cooled by liquid nitrogen down to -196°C . After that, the specimen is transferred to a Dewar with liquid hydrogen for further cooling. The specimen at 253°C is transferred from the Dewar, by means of a special device for rapid transference, to the clamps of the ram impact instrument, where the specimen is placed automatically and correctly. The interval of time from the moment of withdrawal of the specimen from the Dewar to the moment of impact is about 0.5 second.

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Such a procedure permits a rapid testing of toughness, at the temperature of liquid hydrogen, of a great number of specimens.

Taking into account the fact that the toughness of strong materials under these conditions exceeds 20 Kg/cm^2 , we selected for our tests a 30-kg ram impact machine of the Scharpi type.

The specimens used in the tests were the Menage type (GOST-1524-42) with a small deviation from OsTa.

1) The length of a specimen was 57 mm; its end was chamfered to facilitate its slippage in the guide tube by which the specimen was fed from the Dewar to the clamps of the ram impact machine.

2) The end of the sample has a 4-mm head 5 mm long to which is attached a thread for transferring the sample from the Dewar to the clamps of the ram impact instrument.

Figure 1 shows a sketch of the specimen.

With the aid of this apparatus, impact tests of 21 specimens were conducted at -253°C on Scharpi's ram impact machine, for three types of metals: copper M-3, brass LS-62 and 59.

In addition, for comparison of the measurement of ^{impact strength} ~~toughness~~ at -253°C , impact tests on a small number of specimens of these same metals were conducted at 20° and -196°C .

Preliminary Temperature Measurements

Accuracy of measurements of impact tests required that the temperature of the specimen be constant at -253°C at the moment of impact.

To verify this basic requirement, a number of experiments were conducted to determine the course and speed of heating of the specimen when removed from the cooling liquid (liquid nitrogen or liquid hydrogen).

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The temperature of the sample was measured with the help of a thermocouple (copper-constantan). One end of the thermocouple was pressed against the specimen, the other end immersed in the Dewar with the liquid nitrogen.

The measurements indicated that a bare copper specimen withdrawn from liquid nitrogen begins to heat up not at once, but in 2 seconds; that is, in an interval of time in the course of which the liquid nitrogen on the surface of the specimen is evaporated.

In experiments with liquid hydrogen it was proved that the interval of time in the course of which the specimen begins to heat up is very small; the temperature of the specimen begins to rise practically instantaneously after the withdrawal of the specimen from the liquid hydrogen, mainly because of the condensation of air on it.

It was necessary to find the conditions for which the specimen would maintain the temperature of liquid hydrogen within the Dewar for a duration of time sufficient to conduct the test (about one second).

Tests of a great number of various thermal insulators of the type of lacquered or paper covers did not give satisfactory results.

Covering the specimen with a soft thick material that absorbs a great quantity of liquid hydrogen turned out to be a good protective means against heating up. Thanks to this, the temperature of the specimen is maintained constant as long as the hydrogen is not evaporated from the covering. Tests showed that this time is about 3 seconds.

It should be noted that during the tests with liquid nitrogen a specimen covered with this material maintains its temperature constant for 20 seconds.

We had to design the testing apparatus in such a way that the testing time-interval would be less than the time taken to keep the temperature of the specimen constant.

In our apparatus this time was about 0.5 second.

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The Apparatus

The system for cooling and transferring the specimen to the clamps of the ram impact machine is shown in the drawing, Figure 2, and photograph, Figure 3.

The apparatus consists of a Dewar flask with a cap ^{upon} which a German-silver tube has been soldered; the tube has a square cross-section for holding the specimen. In the lower part, the tube has openings and ends with a small bottom. A pourer for filling the Dewar with liquid hydrogen and a tube for drawing off the evaporated hydrogen to the gas holder are also attached to the cap. The German-silver tube is closed with a lid that is opened when the specimen is immersed in or withdrawn from the Dewar.

The specimen is attached to a thin wire which runs on the clamps of the ram impact machine inside a conducting tube-like guide.

With the aid of this wire the specimen is first immersed into the Dewar with liquid nitrogen where it is cooled down to -196°C . Then the specimen is transferred to the Dewar with liquid hydrogen where the specimen takes on the temperature of -253°C .

Thereupon the lid of the tube is opened and, with the help of the thread, the specimen in the guide tube is quickly transferred to the clamps of the ram impact machine.

At the moment that the transfer of the specimen begins the pendulum of the ram impact machine begins to fall and the specimen is smashed in about 0.5 second after the specimen's removal from the liquid hydrogen.

Such speed required the automatic accurate emplacement of the specimen upon the clamps of the ram impact machine. This is done by means of springs and a stopping device.

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The specimen which is quickly withdrawn by the thread from the Dewar with liquid hydrogen is always set up automatically so that 1) the central area of the blade and the notch of the specimen are in alignment (the deviation amounted to about 0.1 mm) and 2) the specimen is tightly compressed against the clamps of the ram impact machine.

The automaticity and correctness of the emplacement of specimens in the clamps of the ram impact machine is tested preliminarily on specimens at room temperature.

Control Temperature Measurements

Control measurements were conducted by us on the heating-up behavior of specimens in the operating state; that is, after their transfer from the Dewar with liquid nitrogen or hydrogen to the clamps of the ram impact machine.

The first control measures were conducted on specimens cooled down to -196°C .

The moment of emplacement of the specimen in the clamps of the ram impact machine can be determined from the knock of the specimen against the arresting device. From this moment the heating-up behavior of the specimen was also determined.

It was found that the bare copper specimen, cooled down to -196°C and then quickly put in place in the clamps of the ram impact machine, begins to heat up in 1.5 to 2 seconds from the moment of emplacement.

Keeping in mind that in our scheme the specimen is smashed in 0.5 second from the moment of its extraction from the Dewar, one can consider with assurance that at the moment of impact the specimen maintains its temperature unchanged. On the basis of this, the impact tests at -196° were conducted on bare specimens.

The control test on the heating behavior was conducted also for specimens cooled to the temperature of liquid hydrogen.

In this case the specimen, protected by flannel and cooled down to -253°C and placed in the clamps of the ram impact machine as described above, begins to heat up in 1.5 to 1.7 seconds from the moment of emplacement.

This comparatively slow heating of the sample is explained by the following two reasons:

- 1) A certain quantity of liquid hydrogen is absorbed by the specimen and when it evaporates the specimen maintains its temperature constant.
- 2) The evaporating hydrogen creates around the specimen a protective gaseous hydrogen envelope which prevents the rapid condensation of air on the specimen.

Based on these experiments, impact tests at -253°C were conducted on specimens protected by flannel. Strict controls were made to see that the duration of stay of the specimen in air up to the moment of impact did not exceed 0.5 seconds, which guaranteed a constant temperature of the specimen at the moment impact.

It was shown by separate experiments that in the limit of error of measurements during the impact tests of the specimens the covering does not influence the results of measurements.

The Results of the Tests

Of the entire number of test specimens (31), the majority (21) were tested for ^{impact strength} ~~toughness~~ at -253°C . The tests at temperatures of the room and liquid nitrogen were conducted for 1 to 2 specimens of each type of metal only for the purpose of comparing the measurements of ^{impact strength} ~~toughness~~ in the transition from 20° to -253°C .

The results obtained from tests are reduced to tabular form (see the table).

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From this data it is evident that:

- 1) The scatter of the values of ~~toughness~~ ^{impact strength} obtained for -253°C is very small. For copper M-3 it is about 2%; for brass LS-62, about 4%; and for brass LS-59, about 7%. This indicates the great reserve of ~~toughness~~ ^{strength} in the studied metals at this temperature.
- 2) The ~~toughness~~ ^{impact strength} of copper M-3 as the temperature decreases from 20°C to -253°C did not diminish, but on the contrary ~~increased~~ ^{increased} a little.

These results agree with the data in our previous works on the investigation of the properties of metals for static loads at low temperatures (vide ZhTF XVI, 1946, pp 515, 527, 539, 551). In this data, the elongation delta and the contraction psi (which characterize the plasticity of metals) of copper increase with decrease in temperature down to -253°C .

According to the data of Pomp, Krisch, Haupt, the ~~toughness~~ ^{impact strength} of electrolytic copper increases in the temperature interval from 20° to -253°C by about 30%.

- 3) The toughness of brass LS-62 and 59 for the transition from -196° to -253°C falls, but is very small, brass LS-62 decreasing by 6% and brass LS-59 by 12%.

These results also agree with the results of our tests on nonferrous alloys under static loads at -196° and -253°C (see our referred earlier work).

Figure 4 a, b, c show photographs of specimens M-3, LS-62, and LS-59 subjected to an impact test.

It is evident from these photographs that the nature of the fracture in the specimens at 20° , -196° , and -253°C is practically unchanged.

In conclusion the authors take this opportunity to express their gratitude to scientific laboratory co-worker L. S. Kan for his assistance during the measurements and also to laboratory master-mechanics N. S. Dogadin and V. P. Khimchenko for their expert preparation of the apparatus for the tests.

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Table: The Influence of Low Temperatures Upon *Impact Strength*
of Copper M-3 and Two Types of Brass, LS-59 & 62.

No. LS-59			No. LS-62			No. M-3		
Toughness in kg/cm ²			Toughness in kg/cm ²			Toughness in kg/cm ²		
20°C	-196°C	-253°C	20°C	-196°C	-253°C	20°C	-196°C	-253°C
7	4.8		12	14.9		23	17.9	
1	3.4		16	15.8		30	21.2	
3	4.1		13		15.9	25		20.2
2		3.7	14		15.1	26		22.2
4		4.3	15		16.0	27		21.9
5		4.1	18		16.6	28		21.6
6		4.3	19		16.9	31		21.5
8		3.7	20		17.0	24		21.9
9		3.6	21		15.6	Average: 21.6 0.5		
10		3.7	Average: 16.2 0.6					
11		4.3						
Average: 4.0 0.3								

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